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Weed Dynamics and Nutrient Uptake of Maize as Influenced by Different Weed Management Practices

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ABSTRACT

Background: Maize (*Zea mays* L.) is the most versatile and emerging food crop of global importance. Weeds are ubiquitous but their presence in wide spaced and initially slow growing crop like maize acts as an obstacle for plentiful harvest. Nutrient uptake by weeds during the first thirty days of maize growth was 59 kg N, 10 kg P_2O_5 and 59 kg K_2O per ha, which was 7-10 times higher than the nutrient uptake by maize.

Methods: The present field experiment was conducted during *Rabi*, 2018-19 under irrigated conditions at wetland farm of S.V. Agricultural College, Tirupati Andhra Pradesh, with ten treatments and three replications in a randomized block design.

Result: Lower density and dry weight of weeds with higher weed control efficiency, lower nutrient uptake by weeds and higher nutrient up take by maize at 80 DAS, kernel and stover yield was recorded with hand weeding twice at 15 and 30 DAS, which was statistically at par with atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 30 g ha^{-1} or tembotrione 120 g ha^{-1} as PoE or atrazine 1.0 kg ha^{-1} as PE *fb* HW at 30 DAS, while these were lowest with weedy check. Higher benefit cost ratio of maize was noticed with both atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 30 g ha^{-1} as PoE (T_3), which was in parity with atrazine 1.0 kg ha^{-1} as PE *fb* tembotrione 120 g ha^{-1} as PoE (T_2) and hand weeding twice at 15 and 30 DAS (T_9). From the present study it may be concluded that atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 30 g ha^{-1} or tembotrione 120 g ha^{-1}as PoE were considered to be the most effective and economic weed management practices to increase the productivity of *Rabi* maize at times of labour scarcity.

Key words: Herbicides, Maize, Nutrient uptake, Weed dynamics, Yield.

INTRODUCTION

In India maize is the third most important field crop after rice and wheat. It is commonly known as “queen of cereals” because of its high genetic yield potential. Its importance lies in the fact that, it is not only used for human food and animal feed (Kumar *et al.,* 2014) but also in the preparation of vast industrial products like corn starch, oil, protein, meal, flour, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, textiles, package and paper industries (Kumar *et al.,* 2003). Wider row spacing and slow initial growth of maize favours quick growth of weeds during early stages of crop growth. Srividya *et al.* (2011) opined that during first 3-4 weeks, the growth of maize is rather slow and during this period weeds establish rapidly and take competitive advantage over the crop. Excluding the environmental variables yield losses in corn due to weeds varied from 28-100 per cent, if they were not controlled during the critical period of crop weed competition (Kumar *et al.,* 2017). Generally weeds reduced crop yields by competing for water, light, nutrients and carbon dioxide. Manual weeding alone is not sufficient for adequate weed control and it may be supplemented with pre emergence herbicides that ensures promising weed control and save the crop from initial weed competition and nutrient drain, while post emergence herbicides were effective during the critical stages of crop growth. Based on the above facts the present investigation was carried out to study the effect of sequential application of pre and post-emergence herbicides on weed dynamics, nutrient uptake and yield of maize.

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MATERIALS AND METHODS

The field experiment was conducted during *rabi,* 2018-19 at wetland farm of S.V. Agricultural College, Tirupati (13.6°N latitude and 79.3°E longitude, at an altitude of 182.9 m above the mean sea level) Andhra Pradesh, India. The soil of the experimental site was sandy clay loam in texture, neutral in soil reaction and moderately fertile being low in organic carbon (0.25%) and available nitrogen (174 kg ha^{-1}), medium in available phosphorus (20.5 kg ha^{-1}) and potassium (186 kg ha^{-1}). Ten treatment combinations *viz,* atrazine 1.0 kg ha^{-1} as pre emergence *fb* one HW at 30 DAS (T_1), atrazine 1.0 kg ha^{-1} as pre emergence *fb* tembotrione 120 g ha^{-1}as post emergence (T_2), atrazine 1.0 kg ha^{-1}as pre emergence *fb* topramezone 30 g ha^{-1}as post emergence (T_3), atrazine 1.0 kg ha^{-1}as pre emergence *fb* halosulfuron methyl 67.5 g ha^{-1} as post emergence (T_4), atrazine 1.0 kg ha^{-1}as pre emergence *fb* 2,4-D amine salt 580 g ha^{-1}as post emergence (T_5), atrazine 1.0 kg ha^{-1}as pre emergence *fb* tembotrione 60 g + 2,4-D amine salt 290 g ha^{-1}as post emergence (T_6), atrazine 1.0 kg ha^{-1}as pre emergence *fb* topramezone 15 g + 2,4-D amine salt 290 g ha^{-1} as post emergence (T_7), atrazine 1.0 kg ha^{-1} as pre emergence *fb* halosulfuron methyl 34 g + 2,4-D amine salt 290 g ha^{-1} as post emergence (T_8), hand weeding twice at 15 and 30 DAS (T_9) and weedy check (T_{10}), laid out in a randomized block design with three replications. Maize hybrid *'DHM-117'* was sown on 19.11.2017 at a spacing of 60 cm × 20 cm with a gross plot size of 5.4 m × 4.6 m and harvested on 13.03.18. Recommended dose of 240 kg N, 80 kg P and 80 kg K ha^{-1} was supplied through urea (522 kg), single super phosphate (500 kg) and muriate of potash (133 kg) to all the plots uniformly. Pre emergence herbicide was applied within 24 hours after sowing and early post-emergence herbicides were applied at 21 DAS of maize. Weed population was counted with the help of 0.5×0.5 m quadrant thrown randomly at two places in each plot and converted to population or density m^{-2}. While recording weed population the biomass was harvested from each quadrant. The different species of weeds collected for assessing the density of weeds was dried separately in hot air oven at 65°C till constant dry weight was reached and converted in to g m^{-2}. Plant samples of crop as well as weeds was collected from all the plots at 80 DAS and both plant and weed samples were dried, ground into fine powder and used for estimation of nitrogen, phosphorus and potassium. Due to large variation in values of density and dry weight of weeds, the corresponding data was subjected to square root transformation ($\sqrt{x + 0.5}$) and the corresponding transformed values were used for statistical analysis as suggested by Gomez and Gomez (1984). A total rainfall of 43.3 mm was received in 2 rainy days with a weekly mean maximum temperature from 38.5 to 25.2°C, with an average of 31.3°C, while the minimum temperature ranged from 21.7 to 13.3°C, with an average of 17.4°C during the maize crop growth period.

RESULTS AND DISCUSSION

Weed floral of the experimental field

The predominant weed species in the experimental site were *Brachiaria ramosa, Cyanodon dactylon, Dactyloctenium aegyptium* (L) Beauv, *Digitaria sanguinalis* (L.) scop, *Cyperus rotundus* L, *Boerhavia erecta* L, *Borreria hispida* (L.) K. Schum, *Celosia argentea* L., *Cleome viscosa* L., *Clitoria ternata* L., *Commelina benghalensis* L., *Corchorus aestuans* L., *Digera arvensis, Euphorbia hirta* L., *Phyllanthus niruri* L., *Trichodesma indicum* L. and *Tridax procumbens* L.

Weed density and dry weight at 80 DAS of maize

Weed dynamics at 80 DAS of maize as influenced by different weed management practices was depicted in Table 1.

Grasses

Hand weeding twice at 15 and 30 DAS recorded significantly lower grass count and dry weight which was closely followed by atrazine 1.0 kg ha^{-1} as pre emergence (PE) *fb* topramezone 30 g ha^{-1} as post emergence (PoE), atrazine 1.0 kg ha^{-1} as PE *fb* tembotrione 120 g ha^{-1} as PoE and atrazine 1.0 kg ha^{-1} as PE *fb* one HW at 30 DAS, without any significant disparity among themselves. Pre followed by post emergence herbicide application of herbicides might have resulted in effective control of weeds during the initial and later stages of crop growth and was equally effective to that of hand weeding twice as accordance with the earlier reports of Puscal *et al.* (2018).

Sedges

Sedge count and biomass at 80 DAS of maize was significantly lower with atrazine 1.0 kg ha^{-1} as PE *fb* halosulfuron methyl 67.5 g ha^{-1} as PoE. This might be owed to the fact that halosulfuron methyl is effective in reducing the sedges than other pre and post emergence herbicides. Hand weeding twice at 15 and 30 DAS, atrazine 1.0 kg ha^{-1} as PE *fb* halosulfuron methyl 34 g + 2,4-D amine salt 290 g ha^{-1} as PoE, atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 30 g ha^{-1} as PoE, atrazine 1.0 kg ha^{-1} as PE *fb* tembotrione 120 g ha^{-1} as PoE and atrazine 1.0 kg ha^{-1} as PE *fb* one HW at 30 DAS were the next best treatments in reducing the density and dry weight of sedges without any significant disparity among themselves.

Broad leaved weeds

Hand weeding twice at 15 and 30 DAS and atrazine 1.0 kg ha^{-1} as PE *fb* one HW at 30 DAS were comparable with one another and recorded significantly lower density and dry weight of broadleaved weeds than weedy check. Broadleaved weeds were not observed in the rest of the weed management practices. This may be due to the fact that pre emergence application of atrazine 1.0 kg ha^{-1} showed a greater impact in controlling the broadleaved weeds during the initial stages of maize growth, whereas post emergence herbicides applied at 21 DAS of maize might have prevented their emergence and growth during the later stages of crop growth, due to which they were not noticed in the respective treatments even at 80 DAS of maize.

The highest density and dry weight of grasses, sedges and broad leaved weeds was registered with weedy check, than rest of the weed management practices tried.

Total weed density and dry weight

The total weed population and biomass at 80 DAS (Table 1)

Table 1: Weed dynamics at 80 DAS of maize as influenced by different weed management practices.

Treatments	Weed density (no m^{-2})*				Weed dry weight (g m^{-2})*				Weed control	Weed index
	Grasses	Sedges	BLW	Total	Grasses	Sedges	BLW	Total	efficiency (%)**	(%)**
T_1: Atrazine 1.0 kg ha^{-1}	2.37	3.41	1.63	4.31	4.64	3.69	1.68	6.01	62.8	10.3
as PE *fb* one HW at 30 DAS	(4.67)	(10.67)	(2.33)	(17.67)	(20.60)	(12.63)	(1.83)	(35.07)	(79.2)	(3.2)
T_2: Atrazine 1.0 kg ha^{-1} as PE	2.31	3.36	1.00	3.96	4.57	3.67	1.00	5.77	63.9	9.9
fb tembotrione 120 g ha^{-1} as PoE	(4.33)	(10.33)	(0.00)	(14.67)	(19.87)	(12.50)	(0.00)	(32.37)	(80.6)	(3.0)
T_3: Atrazine 1.0 kg ha^{-1} as PE	2.23	3.26	1.00	3.83	4.40	3.65	1.00	5.62	64.7	7.5
fb topramezone 30 g. ha^{-1} as PoE	(4.00)	(9.67)	(0.00)	(13.67)	(18.33)	(12.30)	(0.00)	(30.63)	(81.8)	(1.7)
T_4: Atrazine 1.0 kg ha^{-1} as PE *fb*	8.75	2.07	1.00	8.94	8.68	2.29	1.00	8.92	46.9	39.3
halosulfuron methyl 67.5 g ha^{-1} as PoE	(75.67)	(3.33)	(0.00)	(79.00)	(74.43)	(4.27)	(0.00)	(78.70)	(53.3)	(40.2)
T_5: Atrazine 1.0 kg. ha^{-1} as PE *fb*	7.74	7.75	1.00	10.91	7.71	5.76	1.00	9.57	42.5	40.0
2,4-D amine salt 580 g ha^{-1} as PoE	(59.00)	(59.00)	(0.00)	(118.00)	(58.47)	(32.27)	(0.00)	(90.73)	(45.8)	(41.4)
T_6: Atrazine 1.0 kg ha^{-1} PE *fb* tembotrione	5.26	6.14	1.00	8.02	6.28	4.62	1.00	7.73	53.8	29.4
60 g + 2,4-D amine salt 290 g ha^{-1} as PoE	(26.67)	(36.67)	(0.00)	(63.33)	(38.47)	(20.33)	(0.00)	(58.80)	(65.1)	(24.3)
T_7: Atrazine 1.0 kg ha^{-1} as PE *fb* topramezone	5.12	6.08	1.00	7.89	6.19	4.38	1.00	7.54	54.7	28.3
15 g + 2,4-D amine salt 290 g ha^{-1} as PoE	(25.33)	(36.00)	(0.00)	(61.33)	(37.43)	(18.47)	(0.00)	(55.90)	(66.6)	(22.6)
T_8: Atrazine 1.0 kg ha^{-1} as PE *fb* halosulfuron methyl	8.12	3.20	1.00	8.69	7.91	3.10	1.00	8.43	49.7	50.4
34 g + 2,4-D amine salt 290 g ha^{-1} as PoE	(65.33)	(09.33)	(0.00)	(74.67)	(61.53)	(8.60)	(0.00)	(70.13)	(58.2)	(59.3)
T_9: Hand weeding twice at 15 and 30 DAS	2.14	2.94	1.52	3.76	4.37	3.08	1.64	5.41	65.8	0.0
	(3.67)	(07.67)	(2.00)	(13.33)	(18.17)	(8.47)	(1.70)	(28.33)	(83.2)	(0.0)
T_{10}: Weedy check	9.50	8.79	4.58	13.67	10.59	6.44	4.30	13.04	0.0	59.0
	(89.33)	(76.33)	(20.33)	(186.00)	(111.47)	(40.03)	(17.53)	(169.43)		(73.5)
SEm±	0.208	0.160	0.144	0.187	0.228	0.160	0.067	0.214	1.19	1.22
LSD (p=0.05)	0.62	0.48	0.43	0.56	0.68	0.48	0.20	0.64	3.6	3.7

*Data in parentheses are original values, which were transformed to $(\sqrt{x + 0.5})$ and analysed statistically.

**Data in parentheses are original values, which were subjected to angular transformation and analysed statistically.

was lower with hand weeding twice at 15 and 30 DAS, which was however, at par with atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 30 g ha^{-1} as PoE, atrazine 1.0 kg ha^{-1} as PE *fb* tembotrione 120 g ha^{-1} as PoE and atrazine 1.0 kg ha^{-1} as PE *fb* one HW at 30 DAS, without any significant disparity among the treatments. Similar results of reduced density and dry weight of weeds with sequential application of herbicides were reported by Dharam *et al.* (2018) and Sandeep *et al.* (2018). The total weeds count and biomass was significantly higher with weedy check (T_{10}), than rest of all the weed management practices performed.

Weed control efficiency (WCE) at 80 DAS

At 80 DAS (Table 1) higher WCE was recorded with hand weeding twice at 15 and 30 DAS, which was in parity with atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 30 g ha^{-1} as PoE, atrazine 1.0 kg ha^{-1} as PE *fb* tembotrione 120 g ha^{-1} as PoE and atrazine 1.0 kg ha^{-1}as PE *fb* one HW at 30 DAS without significant disparity among them. Reduced density and dry weight of weeds from the initial stages of crop growth in the above treatments might have resulted in higher weed control efficiency. The present findings were in accordance with the earlier findings of Mukherjee and Rai (2015).

Weed index

Lowest weed index was registered with atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 30 g ha^{-1} as PoE (T_3), which was at par with atrazine 1.0 kg ha^{-1} as PE *fb* tembotrione 120 g ha^{-1} as PoE (T_2) and atrazine 1.0 kg ha^{-1} as PE *fb* one HW at 30 DAS (T_1), without significant disparity among them. Lower weed index might be due to effective control of weeds at all the stages of crop growth by sequential use of pre and post emergence herbicides. Similar results of lower weed index with atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 30 g ha^{-1} as PoE was reported by Rao *et al.* (2016) and Kamble *et al.* (2015). Highest weed index was noticed with weedy check (T_{10}) and this might be due to poor weed control efficiency that resulted in lower yields.

Nutrient uptake by maize at 80 DAS

Higher uptake of nitrogen (N), phosphorus (P) and potassium (K) by maize at 80 DAS (Table 2) was noticed with hand weeding twice at 15 and 30 DAS (T_9), which was however in parity with atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 30 g ha^{-1} as PoE (T_3), atrazine 1.0 kg ha^{-1} as PE *fb* tembotrione 120 g ha^{-1} as PoE (T_2) and atrazine 1.0 kg ha^{-1} as PE *fb* one HW at 30 DAS (T_1), in the order of descent. Better weed control efficiency with lower density and dry weight of weeds in the above treatments might have enabled the crop for superior dry matter production that in turn might lead to higher uptake of N, P and K. Similar findings were reported by Gaurav *et al.* (2018). Lowest nutrient uptake by the crop was noticed with weedy check (T_{10}) and this might be attributed to poor weed control and lower drymatter production by maize at all the stages of crop growth. These results confirmed with the findings of Pradeep *et al.* (2017).

Nutrient uptake by weeds in maize at 80 DAS

Significantly lowest nitrogen, phosphorus and potassium uptake by weeds in maize at 80 DAS (Table 2) was recorded with hand weeding twice at 15 and 30 DAS (T_9), which was closely followed by atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 30 g ha^{-1} as PoE (T_3), atrazine 1.0 kg ha^{-1} as PE *fb* tembotrione 120 g ha^{-1} as PoE (T_2) and atrazine 1.0 kg ha^{-1} as PE *fb* one HW at 30 DAS (T_1), which in turn maintained parity among them. Lower nutrient removal by the weeds might be due to higher weed control efficiency and lower weed index also reported by Swapna *et al.* (2017). Higher nutrient *viz.,* N, P and K uptake by weeds in weedy check (T_{10}), may be owed to lower weed index, higher density and

Table 2: Nutrient up take by maize and weeds as influenced by weed management practices at 80 DAS of maize.

Treatments	Maize			Weeds		
	N	P	K	N	P	K
T_1: Atrazine 1.0 kg ha^{-1} as PE *fb* one HW at 30 DAS	0.18	0.84	1.92	111.7	33.0	181.6
T_2: Atrazine 1.0 kg ha^{-1} as PE *fb* tembotrione 120 g ha^{-1} as PoE	0.15	0.83	1.87	113.2	33.5	184.5
T_3: Atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 30 g. ha^{-1} as PoE	0.14	0.80	1.85	116.3	34.1	186.7
T_4: Atrazine 1.0 kg ha^{-1} as PE *fb* halosulfuron methyl 67.5 g ha^{-1} as PoE	2.50	1.18	4.05	75.0	16.8	106.7
T_5: Atrazine 1.0 kg. ha^{-1} as PE *fb* 2,4-D amine salt 580 g ha^{-1} as PoE	3.28	1.36	4.43	73.6	16.1	105.0
T_6: Atrazine 1.0 kg ha^{-1} PE *fb* tembotrione 60 g + 2,4-D amine salt 290 g ha^{-1} as PoE	1.38	1.03	3.38	94.4	22.8	131.3
T_7: Atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 15 g + 2,4-D amine salt 290 g ha^{-1} as PoE	1.32	1.02	3.21	98.1	23.2	132.0
T_8: Atrazine 1.0 kg ha^{-1} as PE *fb* halosulfuron methyl 34 g + 2,4-D amine salt 290 g ha^{-1} as PoE	2.67	1.19	4.08	59.1	11.6	74.7
T_9: Hand weeding twice at 15 and 30 DAS	0.12	0.81	1.81	118.9	34.5	188.8
T_{10}: Weedy check	3.72	1.75	4.89	44.7	6.8	55.7
SEm±	0.087	0.043	0.099	2.76	1.30	4.27
CD (P=0.05)	0.26	0.13	0.30	8.3	3.9	12.8

Table 3: Yield attributes, yield and economics of maize as influenced by weed management practices.

Treatments	Cob length (cm)	Cob girth (cm)	Number of kernel rows cob^{-1}	Number of kernels row^{-1}	Number of kernels cob^{-1}	Kernel yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
T_1: Atrazine 1.0 kg ha^{-1} as PE *fb* one HW at 30 DAS	20.21	17.03	15.3	31.0	462	7403	9987	96239	66865	3.3
T_2: Atrazine 1.0 kg ha^{-1} as PE *fb* tembotrione 120 g ha^{-1} as PoE	20.24	17.40	15.5	31.3	469	7421	10007	96469	68245	3.4
T_3: Atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 30 g. ha^{-1} as PoE	20.85	17.53	15.6	31.3	470	7518	10154	97730	69316	3.4
T_4: Atrazine 1.0 kg ha^{-1} as PE *fb* halosulfuron methyl 67.5 g ha^{-1} as PoE	16.35	12.20	11.4	25.6	386	4575	6902	59471	29722	2.0
T_5: Atrazine 1.0 kg. ha^{-1} as PE *fb* 2,4-D amine salt 580 g ha^{-1} as PoE	16.27	12.03	11.3	25.6	383	4482	6885	58270	31571	2.2
T_6: Atrazine 1.0 kg ha^{-1} PE *fb* tembotrione 60 g + 2,4-D amine salt 290 g ha^{-1} as PoE	18.27	14.30	13.8	28.0	415	5787	8247	75235	47773	2.7
T_7: Atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 15 g + 2,4-D amine salt 290 g ha^{-1} as PoE	18.29	14.47	13.9	28.1	422	5922	8153	76990	49433	2.8
T_8: Atrazine 1.0 kg ha^{-1} as PE *fb* halosulfuron methyl 34 g + 2,4-D amine salt 290 g ha^{-1} as PoE	14.26	10.27	11.0	22.1	347	3116	5458	40504	12279	1.4
T_9: Hand weeding twice at 15 and 30 DAS	20.96	17.60	15.9	31.9	471	7650	10304	99448	67424	3.1
T_{10}:Weedy check	11.30	8.70	9.6	19.7	286	2025	3934	26325	1251	1.0
LSD (p= 0.05)	0.632	0.492	0.45	0.61	8.8	179.2	342.3	2331.5	2331.5	0.09
	1.89	1.47	1.3	1.8	27	537	1025	6987	6987	0.2

*PE-Pre emergence, PoE-Post emergence.

dry weight of weeds during the entire growing period of maize (Mahadevaiah and Sagar, 2014).

Yield of maize

The highest yield attributes, kernel and stover yield of maize (Table 3) was recorded with hand weeding twice at 15 and 30 DAS (T_9), which was however, comparable with application of atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 30 g ha^{-1} as PoE (T_3), atrazine 1.0 kg ha^{-1} as PE *fb* tembotrione 120 g ha^{-1} as PoE (T_2), atrazine 1.0 kg ha^{-1} as PE *fb* one HW at 30 DAS (T_1), without any significant disparity among them. This might be due to reduced competition between the crop and weeds for the existing resources throughout the crop growing period enabling the crop for maximum utilization of nutrients, moisture, light and space, which enhanced the vegetative and reproductive potential of the crop that reflected in the form of higher kernel and stover yield of maize as also noted by Parameswari *et al.* (2017). The lowest kernel yield of maize was resulted with weedy check (T_{10}). This was mainly due to greater competition for the growth resources among the crop and weeds as evident by the lowest crop stature, yield attributes and finally kernel yield of maize.

Economics

Higher gross returns was realized with hand weeding twice at 15 and 30 DAS (T_9), which was in parity with atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 30 g ha^{-1} as PoE (T_3), atrazine 1.0 kg ha^{-1} as PE *fb* tembotrione 120 g ha^{-1} as PoE (T_2) and atrazine 1.0 kg ha^{-1} as PE *fb* one HW at 30 DAS (T_1), in the order of descent. This may be attributed to higher kernel yield due to reduced crop weed competition (Varshitha *et al.*, 2019), where as higher net returns was reported with atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 30 g ha^{-1} as PoE (T_3), which was however, comparable with atrazine 1.0 kg ha^{-1} as PE *fb* tembotrione 120 g ha^{-1} as PoE (T_2), hand weeding twice at 15 and 30 DAS (T_9) and atrazine 1.0 kg ha^{-1} as PE *fb* one HW at 30 DAS (T_1) in the order of descent. The higher net returns might be due to increased yields and reduced cost of cultivation as also reported by Aruna *et al.* (2018),

Higher benefit cost ratio of maize was noticed with both atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 30 g ha^{-1} as PoE (T_3), which was statistically at par with atrazine 1.0 kg ha^{-1} as PE *fb* tembotrione 120 g ha^{-1} as PoE (T_2) and hand weeding twice at 15 and 30 DAS (T_9). Atrazine 1.0 kg ha^{-1} as PE *fb* one HW at 30 DAS (T_1) was at par with T_9 but significantly lower than T_3 and T_2 during the period of study. Lower weed index, higher yields and reduced cost of cultivation might have increased the benefit cost ratio in the above treatments. The findings were in accordance with Mitra *et al.* (2018). The gross returns, net returns and benefit cost ratio were lowest with weedy check (T_{10}) might be due to declined yields due to the presence of excessive weed population.

CONCLUSION

In conclusion, the present study has revealed that atrazine 1.0 kg ha^{-1} as PE *fb* topramezone 30 g ha^{-1} or tembotrione 120 g ha^{-1} as PoE were considered to be the most effective weed management practices to increase the productivity in *Rabi* maize at times of labour shortage.

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